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The principle objective of this project is the identification and development of ecological models that can be used in support of military land use decisions, especially those associated with the DoD training mission. The ecological models implemented as part of this project are components of the Conservation Thrust's "DoD Land Management Toolbox" and are compatible with the Integrated Dynamic Landscape Analysis and Modeling System *IDLAMS) that serves as the integrating framework for the Toolbox.

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# Ecological Modeling for Military Land Use Decision Support: Interim Progress Report for Ecological Modeling (Project CS/758/4567)

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# 1 Executive Summary

The Strategic Environmental Research and Development Program (SERDP) of the Department of Defense (DoD) is sponsoring research on the application of ecological modeling for military land-use decision support (Project CS/758/4567). The principle objective of this project is the identification and development of ecological models that can be used in support of military land use decisions, especially those associated with the DoD training mission. The ecological models implemented as part of this project are components of the Conservation Thrust's "DoD Land Management Toolbox" and are compatible with the Integrated Dynamic Landscape Analysis and Modeling System (IDLAMS) that serves as the integrating framework for the Toolbox.

Habitats and the plant and animal populations that depend upon those habitats are the targets of the ecological modeling. This approach encompasses, for example, the impact of dismounted and mounted troop training (including tracked-vehicle traffic) on the persistence and quality of habitat utilized by threatened and endangered species (TES) or other species of conservation concern. A landscape perspective is explicit in all aspects of the project. All of the ecological modeling is spatially-explicit and uses georeferenced data in a Geographic Information System (GIS) as model input. Model outputs are also georeferenced, stored as data layers in the GIS, and displayed as raster maps. Beyond spatially-explicit modeling, the project's landscape perspective emphasizes the importance of spatial context and habitat continuity.

Fort Knox, Kentucky is being used as a case study site. Consideration of conservation issues at Fort Knox has helped define our modeling objectives and approaches. Moreover, we are using data from Fort Knox to develop, implement, and test our models. The Fort Knox case study will demonstrate the general appropriateness, data requirements, and applicability of the models for other training installations. We will expand the approach developed at Fort Knox by developing a model to address a pressing DoD TES problem: red-cockaded woodpecker. We are working with CERL and the national red-cockaded woodpecker recovery team to identify how our models can best support their management efforts. Fort Stewart, Georgia, one of the ten most critical red-cockaded woodpecker sites, will be our test bed. We anticipate using information from our ongoing work with Sam Houston State University to assist in this effort.

## 2 Introduction

The Department of Defense (DoD) Strategic Environmental Research and Development Program (SERDP) is sponsoring research on ecological models for the assessment of military land use. This interim report describes the logic and objectives of the ecological modeling component of the Oak Ridge National Laboratory (ORNL)–Pacific Northwest National Laboratory (PNNL) project (Project CS/758/4567). It describes a modeling approach for meeting those objectives that has emerged from project's investigations to date, and it describes the ecological modeling which contributes to that approach. This report is an overview; specific models developed by the project will be documented in subsequent reports.

## 3 Problem Statement

The principle objective of this research project is the identification and development of ecological models that can be used in support of military land use decisions, especially those associated with the DoD training mission. These decisions occur at two levels: (1) in the near-term scheduling and allocation of training areas at DoD training installations and (2) in longer-term master planning and site management. In both cases, the goal is to *maximize* the area that can be used for training while simultaneously *minimizing* impacts on natural resources (e.g., the habitat of threatened and endangered species (TES)). Our approach to achieving this objective explicitly considers the spatial and temporal coincidence of training activities with ecological resources of conservation concern and the impact that training may have on those resources.

Training may have diverse consequences for a variety of natural resources. We have selected habitats and the plant and animal populations that depend upon those habitats as the targets of our ecological modeling. Military training can alter vegetation type, cover, and structure (e.g., plant density and height). Changes in vegetation are often reflected in altered habitat quality and quantity for associated plant and animal species. Thus we are pursuing a modeling approach which interprets changes in vegetation as changes in habitat and translates these changes into impacts on the plant and animal populations that utilize those habitats. Our approach encompasses, for example, the impact of dismounted and mounted troop activities

(including tracked-vehicle traffic) on the persistence and quality of habitat utilized by TES or other species of conservation concern. We do not currently consider the impact of noise or smoke and obscurants on the biology and behavior of those species. These are important considerations but beyond the current scope of this project.

The use of ecological models in the assessment of conservation or ecological concerns is viewed as a complement to existing mission suitability assessments such terrain analysis or mission safety/risk analysis. The logic of the assessment assumes that training has priority. The role of the ecological modeling is to synthesize spatially-explicit ecological information and present it in a form that can be easily incorporated into training and other land-use decision protocols and procedures. We believe that ecological models can provide inputs that lead to least-cost refinements of training and other land-use decisions, refinements which accommodate critical conservation concerns but do not unnecessarily or inappropriately interfere with the training mission.

# 4 Decision Support Framework

We pursue our ecological modeling within the context of a modular computerized decision support system (Figure 1). Development of this system as a "DoD Land Management Toolbox" is a coordinated effort among SERDP Conservation Thrust Projects (see Appendix A). The ecological models described in this interim report as part of SERDP Project CS/758/4567 are being developed as components of this toolbox and are compatible with the Integrated Dynamic Landscape Analysis and Modeling System (IDLAMS) that serves as the integrating framework for the "toolbox" However, the models also exist as "stand alone" products.

# 5 Ecological Modeling

## 5.1 Landscape Framework and Perspective

A landscape perspective is explicit in all aspects of our ecological modeling. A central premise of this perspective is that locations within a training installation vary in their relative conservation

concern and in their relative sensitivity to impacts of military training. With explicit spatial knowledge of these relative differences, training activities can be targeted to areas of relatively low conservation concern and sensitivity. Thus, more critical or sensitive areas (some of which may be protected by State and Federal regulation) can be protected while continuing the training mission. Similarly, longer-term land use can be planned to maximize sustained use of the installation as a training facility.

All of the ecological modeling in this project is spatially-explicit and uses georeferenced data as model input. All georeferenced model inputs are described by data maps stored in a Geographic Information System (GIS). Model outputs are also georeferenced, stored as data layers in the GIS, and displayed as raster maps. When the models are integrated within the DoD Land Management Toolbox (Figure 1), IDLAMS will provide the spatially-explicit model inputs and display model results.

Ecological modeling serves several functions within the context of military land-use decision support. First, habitat models are used to characterize the spatial distribution of habitats across a site. Second, dynamic vegetation/habitat models are used to describe the impact of training on habitat type and quality. Finally, population models are used to relate habitat to plant and animal populations that use those habitats and to describe how changes in habitat quality and distribution impact those populations. Each of these modeling efforts is described in greater detail below.

We are using Fort Knox, Kentucky as a case study for our ecological modeling (see SERDP #758 Project Report, Ecological Modeling for Military Land use Decision Support: Interim Progress Report for Case Studies). Consideration of natural resource and conservation concerns at Fort Knox has assisted in defining our modeling objectives and approaches. Moreover, we are using data from Fort Knox to develop, implement, and test our models. The Fort Knox case study will demonstrate the general appropriateness, data requirements, and applicability of the models for other training installations. Further evaluation of the approach and models will occur with application at another DoD training installation of different ecology. Selection of this site is being coordinated with other participants in the DoD Land Management Toolbox effort (Figure 1).

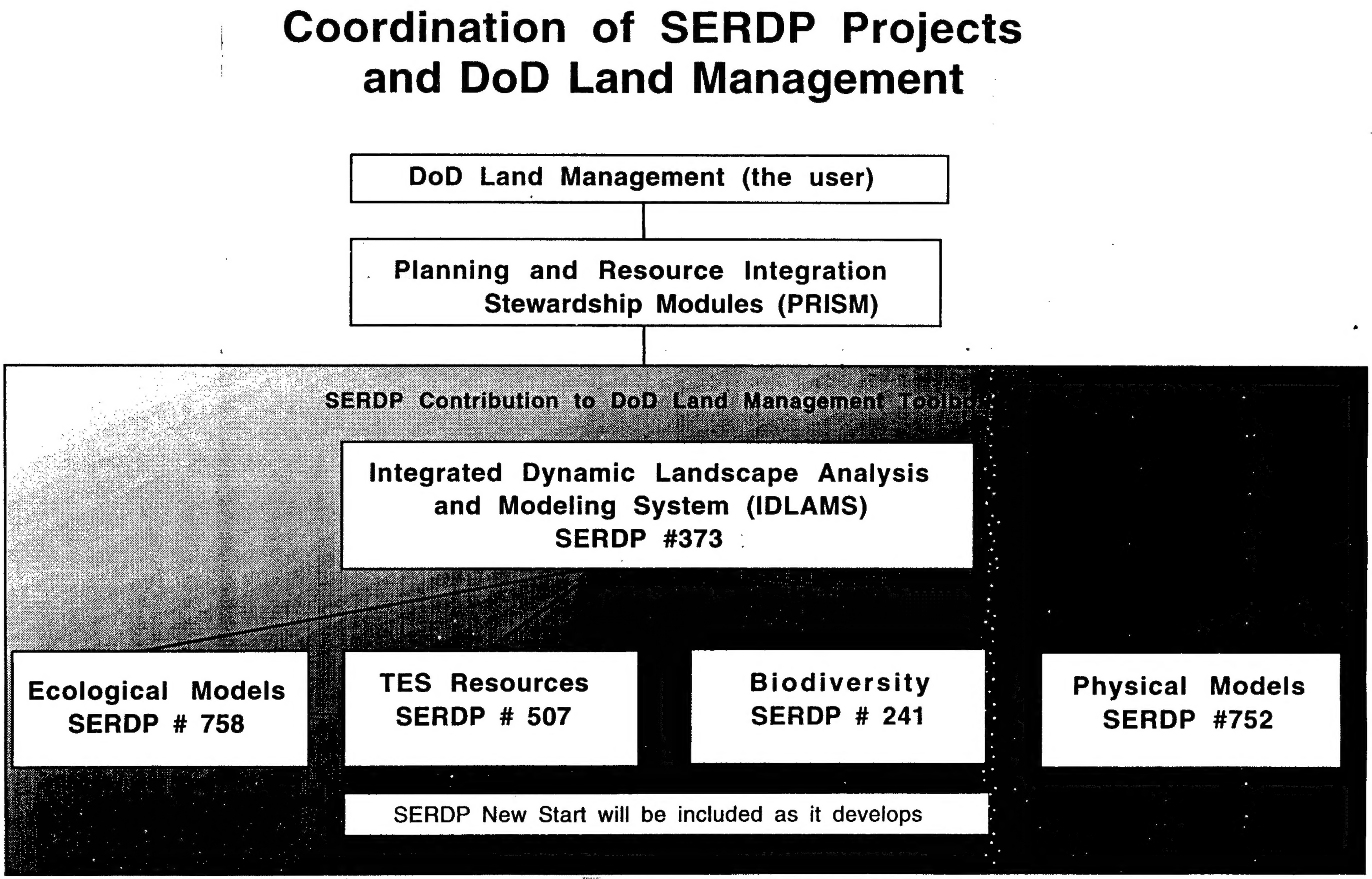


Figure 1: Coordination of SERDP projects and DoD land management. Coordination will occur across each SERDP project listed above including the New Start.

## 5.2 Habitat Characterization

### 5.2.1 Land Use and Land Cover

Primary characterization of habitat for a site is provided by a digital map of land use/land cover. These data are often derived from satellite imagery and was selected as a primary data layer on the expectation that it would be available for most training installations. This was not the case, however, for Fort Knox, and project members (primarily W. W. Hargrove) have devised a procedure for using Land Condition Trend Analysis (LCTA) data to classify LandSat Thematic Mapper (TM) satellite imagery data into a description of land use/land cover at 30 meter resolution. These data should be available for most installations and the procedure should have general applicability in those instances when a primary land cover/land use data layer is not available.

### 5.2.2 GIS Modeling of Habitat

Habitat characterization using available landcover/landuse maps or remote sensing imagery may be too coarse. The categories may be too general or broad to be useful for evaluating habitat quality or the impacts of training. For example, the category "Deciduous Forest" used in mapping landcover for Fort Knox undoubtedly includes forests of different type, age, and structure of variable importance for biological populations and which differ in their potential sensitivity to military training impacts. In contrast, plant and animal populations may be more specific or discriminating in their choice of habitat. For example, the Cerulean Warbler (*Dendroica cerulea*), a species of conservation concern at Fort Knox, is associated with mature hardwood forest with closed canopy. A simple identification of Cerulean Warbler habitat with Deciduous Forest landcover would overestimate available habitat, and could unnecessarily constrain training activities. Similarly, Henslow's Sparrow (*Ammodramus henslowii*), listed as a species of Special Concern by the Kentucky State Nature Preserves Commission, nests at Fort Knox during the summer and apparently prefers areas with dense cover of native perennial grasses over areas of sparse annuals or exotic grasses. A simple habitat characterization as "Grassland" would be to coarse. In addition, habitats known to be of special management

concern (e.g., limestone barrens at Fort Knox) may not be discriminated by existing landcover maps or satellite imagery. Models which predict the existence of particular habitat types as functions of land cover and other data layers in the GIS can be used to fill these gaps and provide more refined characterizations of habitat. For example, project members (primarily L. K. Mann, W. W. Hargrove, and R. Washington-Allen) have implemented a model that predicts the occurrence of limestone barrens at Fort Knox using georeferenced thematic data in the Fort Knox GIS. Similarly, GIS habitat models for Cerulean Warbler and Henslow's Sparrow at Fort Knox have been developed.

### 5.2.3 Simulation Modeling of Habitat and Habitat Dynamics

Even the refined habitat characterization by GIS modeling may be too coarse for effective coupling of habitat to plant and animal populations. First, species often respond to variation in vegetation life form (e.g., perennial grass versus annual grass) and structure (e.g., percent cover or vegetation height); consequently, habitat characterization by life form composition and structure may be more appropriate than simple characterization by habitat type. Second, changes in these characteristics over time in response to natural disturbance and the disturbance associated with military training will affect the spatial distribution of habitat. Ultimately, a model that predicts changes in life form and vegetation structure from local conditions (e.g., soil type) and disturbance history is required to map changes in the distribution of habitat utilized by species of conservation concern.

The project (primarily R. N. Kickert) is developing a dynamic and spatially-explicit vegetation model that simulates changes in the structure of the vegetation life forms that are most likely to be impacted by military field training, namely shrub, grass, and forbs. Changes in percent cover and height of these life forms is simulated at weekly and monthly time steps. The model includes effects of trampling and inadvertent fire from military field training activities. Extensive reviews of the scientific literature on vegetation trampling, soil compaction, and fire ecology are underway for the purpose of equipping the model with state-of-the-science information and knowledge. Some of the model's required inputs come from the GIS maps, while others come from LCTA data. Simulated output responses for vegetation change over space

are entered into the GIS for display and analysis. These changes are interpreted as changes in habitat distribution and quality for species of conservation concern, but can be viewed as changes in vegetation cover in their own right.

Our dynamic vegetation model complements the CERL Carrying Capacity model. Our model simulates changes in vegetation structure (e.g, percent cover and height) because of its importance for the characterization of wildlife habitat. The Carrying Capacity model simulates changes in community composition and biomass (McClendon et al. 1996). These are different descriptions of vegetation state, currently requiring different modeling approaches. In the future an integration of the two approaches should be possible, and we are pursuing our model development in communication with David Price and others at CERL.

## 5.3 Relating Habitat to Plant and Animal Populations

We have identified four general approaches for linking habitat to the plant and animal populations that depend upon that habitat: (1) simple habitat association, (2) habitat quality and suitability models, (3) landscape connectivity models, and (4) spatially-explicit population models. We have applied only the latter at Fort Knox. However, we have used a landscape connectivity model in a test application of the assessment framework described in this report (Dale et al. 1996, submitted manuscript). Moreover, we propose to explore the other approaches as we expand our efforts to include other DoD installations, and we summarize each approach here.

### 5.3.1 Simple Habitat Association

Plant and animal populations can be associated with particular habitats using simple rule-based models of the form: if habitat $h$, then species $s$. For example, the Great Plain's Ladies Tress (*Spiranthes magnicamporum*), listed as a threatened species by the Kentucky State Nature Preserves Commission (KSNPC), occurs in limestone glade/barren habitat at Fort Knox. A simple habitat association model would predict the (potential) presence of this species wherever limestone glade/barren habitat occurred. Similarly, the cerulean warbler (*Dendroica cerulea*), a species of conservation concern at Fort Knox, is associated with mature bottomland hardwood

forest. A habitat association model would predict the presence of this warbler wherever mature bottomland hardwood forest occurred at Fort Knox.

These habitat association models are exceptionally simple. Precisely because they are so simple, they are easily constructed and easily implemented. However, while they do provide a first estimate of resource value associated with different habitats using minimal information, the estimate is coarse and almost certainly overestimates the spatial distribution of the species of concern. We propose these models only as first estimates of the spatial distribution of habitat of conservation concern.

### 5.3.2 Habitat Quality and Suitability

The simple habitat association models assume that all occurrences of a habitat type are of equal importance or value to the associated populations. However, habitat quality or suitability varies within habitat type and this variation may be reflected in the importance of a particular occurrence of that habitat for species that use that habitat type. In other words, the value associated with a habitat type may vary with location. With additional information and effort, the assessment of habitat value can be refined using multivariate statistical methods that relate quantitative measurements of habitat to the presence-absence or densities of plant and animal populations. These methods require significant effort and considerable amounts of high quality data that are often hard to collect, but they yield quantitative models of habitat quality (Maurer 1986). A related, but less data-intensive, approach is incorporated in the habitat evaluation procedures (HEP) of the U.S. Fish and Wildlife Service (Divison of Ecological Services 1980). HEP is a procedure for estimating a habitat suitability index (HSI) that ranks occurrences of habitat from low quality (suitability) to high quality.

Multivariate methods and HEPs or HSIs are normally not spatially explicit. However, the general approach can be extended to incorporate spatial information and yield maps of habitat quality (Nisbet et al. 1983). Spatially-explicit habitat quality models of this nature merit further development. Their data requirements are considerable, and their efficacy is largely untested. Consequently, we have not pursued them at Fort Knox. However, we will explore their development for installations and applications that are part of the next phase of our study.

### 5.3.3 Landscape Structure and Connectivity

The assessment of habitat suitability achieved by either Simple Habitat Association Models or revised Habitat Evaluation Procedures involves individual and effectively independent locations. It ignores the spatial context of these locations. It ignores the potential importance that spatial continuity and pattern of habitat may have for dependent populations. The importance of a habitat-type may be a function of the total area of that habitat or of the proportion of the installation area occupied by that habitat. Rare habitats may be disproportionally more important than common habitats, or vice versa. Investigations of landscape pattern and habitat fragmentation have indicated that connectivity, the spatial pattern, adjacency, and continuity of habitat that allows organisms or reproductive propagules to move within and among habitat patches, may be crucial to a populations utilization of the landscape. Small isolated patches may be less important than large contiguous patches. Habitat that effectively connects patches of habitat (e.g., corridors) may be critical to the viability of a population on the landscape. For example, continuous forested riparian corridors have been identified as important to bat species at Fort Knox, including the gray bat (*Myotis grisecens*) and the Indiana bat (*Myotis sodalis*), both listed as Federally Endangered species. Occurrences of riparian habitat that are part of a continuous corridor are presumably of greater value to these bat populations than small isolated occurrences of even highly suitable habitat (with a high HSI from a HEP). In short, a landscape perspective and analysis can alter the assessment of habitat importance and value. We have used Scott Pearson's cell-based model of patch connectivity (Dale et al. 1994) to simulate available habitat in an application for Oak Ridge Reservation (Dale et al. 1996, submitted manuscript). Whether as part of a landscape connectivity model or the spatial explicit population models described below, consideration of spatial context and continuity should be part of any modeling of habitat quality.

### 5.3.4 Spatially Explicit Population Models

All of the modeling described above focuses on habitat. It assumes an association between habitat and plant and animal populations, perhaps weighted by habitat suitability. If the

habitat is there, the models presume the presence of individuals of associated species. None of the models predict numbers of individuals at a location or changes in those numbers over time. Yet, locations with many individuals will presumably be of greater conservation concern than locations with only one individual. Predicting the spatial distribution of individuals or population density requires spatially explicit population models.

Spatially explicit population models (SEPM) (Dunning et al. 1995) describe the dynamics of plant and animal populations in heterogeneous landscapes. The models are spatially explicit in that demographic parameters vary with location in the landscape, often as a function of habitat type and suitability. Because they are spatially explicit the models can be used to investigate the consequences of changes in landscape pattern and structure (e.g., habitat distribution and continuity) for the viability and persistence of populations on the landscape.

SEPMs can be divided into two classes: individual-based models and population-based models (Dunning et al. 1995). Individual-based models track the location of individuals across the landscape. These models are appropriate for larger vagile animals (e.g., birds) that move readily over fairly large portions of the landscape during the breeding or reproductive portion of their life cycle. Their movements integrate the finer scale heterogeneity of the landscape, and the integration influences their reproductive fitness and demographic parameters associated with that individual. Population-based models describe the state of a population (e.g., density-individuals per unit area) at a specific location. These models are appropriate for relatively sessile organisms (e.g., plants) or small animals (e.g., insects) which complete their reproductive cycle in an area less than or equal to the resolution of the data used to describe spatial heterogeneity of the landscape (e.g., the cell size of a cell-based description of the landscape). Movement between locations (cells) is limited to the dispersal phase of the life cycle and demographic parameters are associated simply with location and not with individuals.

Guided by conservation concerns at Fort Knox, we have developed a spatially explicit population model for territorial migrant birds breeding in the heterogeneous landscapes of military installations. The model is of the individual-based type, but does not track local movement of individuals since the critical dispersal movement is associated with long distance migration. The model complements existing spatially explicit or mobile animal population models (MAPs)

that describe the local dispersal of juveniles in resident populations. In brief, the model is designed to assess how changes in habitat quantity, quality, and spatial distribution affect the reproductive success and persistence of territorial migrants. Dispersal and establishment of new territories is a phenomenon associated with returning migrants. Territories are distributed among patches of suitable habitat using logistic regressions of the relationship between the probability of species' occurrence and patch area. The spatial distribution of habitat is described by a cell-based landscape map. Cells of suitable habitat are aggregated to form patches and territories. Reproductive success of each territory is a function of species- or population-specific demographic parameters, the condition (e.g., age) of individuals occupying the territory, habitat quality within the territory, and location of the territory (e.g., distance to patch edge). Juveniles and adults migrate from the landscape at the end of the breeding season. Population dynamics during the nonreproductive season are not modeled explicitly. Overwinter survival, for example, is treated as a simple probability. Returning migrants are redistributed among patches of suitable habitat to complete the annual cycle. The redistribution accounts for site fidelity and competition among new individuals seeking territory for the first time.

We have implemented the model for Henslow's Sparrow (a continental migrant) and Cerulean Warbler (a neotropical migrant) at Fort Knox, Kentucky. Full documentation of these implementations will be presented in a subsequent report.

The territorial migrant model will be integrated with IDLAMS. As part of this integration, the model will be applied to the Henslow's Sparrow at Fort Riley, Kansas. IDLAMS will provide the habitat map; output from the territorial migrant model will be incorporated into IDLAMS. Similarly, we will produce a spatially-explicit population model for Karner Blue Butterfly (*Lycaeides melissa samuelis*) that will be incorporated into IDLAMS as it is applied to Fort McCoy, Wisconsin (Appendix A).

For the past several months, we have been working with CERL staff involved with the TES Resources project (Figure 1) to identify the best candidate for future our modeling task. Red-cockaded woodpecker (*Picoides borealis*) (RCW) is one of the most significant TES on military lands. Furthermore, the preferred long-leaf pine habitat for these birds is highly fragmented across their range, and military reservations are among the major locations where there

is still substantial habitat remaining. While much has been learned about the ecology of this bird, two key issues appear to be unresolved. First, the distribution of the red-cockaded woodpecker across the southeastern United States and Texas suggests that metapopulation dynamics (Levins 1969) may be influencing the overall population. This would mean that management of local populations, such as occur on DoD facilities, should be planned in a larger context. Modelling this metapopulation structure would be a useful tool to guide the recovery plan for the species and the actions of DoD land managers. Second, management for red-cockaded woodpeckers requires aggressive action (e.g., periodic burning) to preserve a habitat that is well-suited for some other species of conservation concern but which may be unsuitable for other species [e.g., Bachman's Sparrow (*Aimophila aestivalis*) (Liu et al. 1995) or Henslow's Sparrow]. A multi-species modeling approach should yield useful insights into the impact of various red-cockaded woodpecker management strategies on the wider issue of biodiversity and ecosystem management.

It is not feasible within our current funding and time constraints to simultaneously address both issues. We are in communication with the national red-cockaded woodpecker recovery team and with others working on red-cockaded woodpecker management to determine where the greatest need is and where we can provide the most benefit. Whichever issue we decide to address, we will utilize the red-cockaded woodpecker population at Fort Stewart, Georgia as a test bed for the model. We expect that the work we are doing with Sam Houston State University on another SERDP-funded task will provide remotely sensed data for use at Fort Stewart and other possible test bed sites (e.g., Sam Houston State Forest).

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# A Memorandum of Coordination Among SERDP Conservation Thrust Land Management Projects

MEMORANDUM TO: Dr. Femi Ayorinde, SERDP Program Manager

FROM: Winifred Hodge, Conservation TTAWG Co-Chair

SUBJECT: Coordination Minutes from May 2, 1996, meeting of the SERDP land management project principal investigators.

DATE: 26 August 1996

1. Attached are the minutes of the coordination meeting held by several of the SERDP conservation land management project principal investigators on May 2, 1996. The minutes have been reviewed by each of the participants.

2. Please contact me, other TTAWG members, or the principal investigators directly, if there are any remaining questions or concerns. Please inform me if a hard copy of this memorandum is required and I will be glad to provide it.

MINUTES OF MAY 2, 1996 COORDINATION MEETING
FOR THREE SERDP CONSERVATION PROJECTS

I. Introduction and Background

Throughout FY95 and FY96, there have been efforts to coordinate all Strategic Environmental Research and Development Program (SERDP)-funded, land management research projects across Department of Defense (DoD) and Department of Energy (DOE) Laboratories and to ensure that SERDP researchers are familiar with outside DoD and DOE land management activities. As explained in Winifred Hodge's message entitled "Coordination Statement for SERDP Land Management Projects" dated 15 December, 1995, the intent of coordination is two-fold: 1) To support a modular computerized decision support system through development of a system framework, sub-models, data, and general information; and 2) To provide the same tools as stand-alone products, since individual SERDP projects were originally developed independent of each other. Additional background and general information can be found in that document and the official minutes of the December 1995 coordination meetings held at Argonne National Laboratory (ANL) and the U.S. Army Construction Engineering Research Laboratories (CERL).

II. Purpose of This Document

The purpose of this document is to officially record the content of one coordination meeting held on May 2, 1996 at Fort Belvoir, VA. A list of participants is attached.

III. Content

Data coordination: All SERDP-funded modellers follow Department of Defense metadata man-

agement standards. However, test bed sites (e.g. DoD installations) are responsible for data collection and the quality of that data. Research groups choose sites and management questions that take advantage of existing data. Researchers assume that the existing data are accurate. A synthesis of existing information about threatened and endangered species (TES) management in the southeastern United States is under development at CERL and Waterways Experiment Station (WES). This information will be useful for future modelling efforts in the region and may provide novel approaches for modelling ecosystem processes and management decisions. Plant community classification schemes will be identified and coordinated among research groups. The use of models is expected to identify additional data requirements. There is not enough money in current projects to support extensive sensitivity analysis or ground truthing, although some will be carried out as model development occurs. Likewise, there is not enough funding to support error budget analysis. It is anticipated that additional funds will be needed to perform extensive sensitivity analysis and validation.

Model documentation: Each research group will produce a documentation report which includes the following sections: 1) a description of the model, 2) logic flow diagram, 3) data requirements, and 4) source code listing. It is anticipated that journal articles will be written to describe uses of the models.

Vegetation modelling issues: Currently, the ANL/CERL Integrated Dynamic Landscape Analysis and Modeling System (IDLAMS) project uses a land cover vegetation model based on successional stages which creates outputs such as cover, biomass, and vegetation type. This is appropriate for certain purposes, e.g. to predict erosion potential or tank damage. Oak Ridge National Laboratory (ORNL) is writing a vegetation dynamics model focused on the structural qualities of vegetation through time and how that relates to the habitat requirements of wildlife species (e.g. to predict impacts of training on both vegetation and wildlife).

Model handshaking: ORNL will provide the Henslow's Sparrow population submodel for incorporation into IDLAMS. ORNL also plans to provide a population model for the Karner Blue Butterfly in conjunction with IDLAMS work at Fort McCoy, WI. ANL, CERL, and ORNL will continue to discuss submodel inputs and outputs to facilitate this high level of coordination. IDLAMS will provide habitat map output, based on the IDLAMS vegetation model. ORNL will use that habitat map to model Henslow's Sparrow population. The output of the Henslow's Sparrow submodel will then fit into the IDLAMS decision analysis module. Information flow among the various submodels and IDLAMS will be through approaches such as ASCII text arrays using Tcl/TK protocol. This is to be accomplished by the end of FY 97.

Remote Sensing Wish List:

1. 5 m digital elevation model (DEM) data
2. arid soil microflora
3. an evaluation of plant community quality for TES
4. surface soil moisture through root zone
5. vegetation information– grasses, shrubs, trees, succelents, evergreen, deciduous, etc.

6. spectral library– site specific, weather and season-defined
7. wildlife censusing with high resolution thermal
8. stress data
9. life form/ height classes of vegetation
10. description and quantification of human activities
11. image processing for aggregation
12. effects of past land uses

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